Soil Moisture and Vegetation Observations During SGP99 Using the PALS Airborne Microwave Radiometer-Radar System

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Abstract – The Passive/Active L/S-band (PALS) airborne microwave sensor was flown for the first time during the 1999 Southern Great Plains (SGP99) experiment. The objective was to acquire a dataset for studying a combined radiometer-radar multifrequency, multipolarization approach to soil moisture sensing under varied terrain conditions. Six days of PALS flight data were acquired over the Little Washita and El Reno areas in Oklahoma, in conjunction with ground-based soil and vegetation in-situ sampling. The data illustrate the different sensitivities of the PALS channels to soil moisture, temperature, surface roughness, and vegetation cover, and will provide a basis for development of passive and active multichannel algorithms for soil moisture sensing.

INTRODUCTION

In many soil moisture remote sensing studies attention has focused on the use of 1.4 GHz (L band) horizontal polarization (H-Pol) radiometer systems. Over varied terrain, the L-band H-pol (LH) channel has better sensitivity to soil moisture than higher frequencies and vertical polarization. As a practical matter, it is simpler and cheaper to build and operate single-channel radiometers for truck-based and airborne experiments. To date, single-channel observations have contributed a substantial experimental database [1]–[5], from which algorithms and science justification can be developed for future spaceborne missions.

Vegetation, surface roughness, surface temperature, and soil texture significantly affect the relationship between LH brightness temperature (T_B) and soil moisture. Algorithms that seek to recover soil moisture from LH T_B measurements must correct for these effects [6], [7]. Ancillary data can be utilized for these corrections. There are limitations, however, on the usage of ancillary data, arising from: sparseness and inaccuracy of some of the data sources; indirect relationships between the ancillary data and microwave model parameters (e.g. NDVI and vegetation water content); and difficulties in co-registering the brightness temperature and ancillary data in time and space and at similar spatial resolutions.

Previous studies have indicated that complementary information on surface characteristics can be obtained by using other sensing channels in addition to LH. The effects of vegetation and surface roughness can be separated from the effects of soil moisture by their different frequency and polarization signatures. Similarly, active (backscatter) measurements are typically more sensitive to surface roughness and vegetation than passive measurements, and can potentially be used to estimate the effects of these characteristics on the passive measurements [8]. Model simulations indicate that improvements approaching a factor of two in soil moisture accuracy, over a larger percentage of land area, may be achievable using a multichannel rather than single channel sensing system. However, there are many assumptions in the models, and such projections need to be tested. Furthermore, the goal of the multichannel approach is not to eliminate the use of ancillary data but to utilize information potentially available in the multiple sensor channels.

PALS SENSOR

The Passive/Active L/S-band Sensor (PALS) [9] is an airborne instrument designed for multifrequency, multipolarization, passive and active microwave sensing. The instrument operates at 1.26, 1.41, 2.69, and 3.15 GHz with dual polarization and a fixed incidence angle between 35° and 55° It is designed to be flown on a C-130 aircraft. The key instrument characteristics are listed in Table 1. Additional instrument details can be found in [9]. The L and S band radar frequencies are designed to be as close as possible to the radiometer frequencies. They cannot be identical since the radiometers use protected frequency bands. At a flight altitude of 1 km, and incidence angle of 40°, the instantaneous 3-dB footprint is approximately 300 x 400 m in all channels. The instrument is non-scanning, thus a single-footprint line swath is sampled beneath the aircraft. The first science flights of PALS took place in July 1999 as part of the 1999 Southern Great Plains (SGP99) experiment. The flights were conducted successfully with only minor instrument problems. Initial processing of the data showed excellent instrument sensitivity and calibration stability.

Table 1: PALS Instrument Characteristics

	Radiometer	Radar
Frequencies	1.41 and 2.69 GHz	1.26 and 3.15 GHz
Polarizations	V and H	VV, HH, VH
Beamwidths	15 deg	
Beam efficiency	92 %	
Cross-polarization	-17 dB	
Incidence angle	35–55 deg	
Spatial resolution	0.4 km (@ 1 km alt)	
RMS noise per footprint	0.2 K	
Noise equivalent σ_o at 1 km altitude		< -45 dB
Calibration stability	0.1 K	0.1 dB
Transmit power		5 W
Duty cycle		8 %

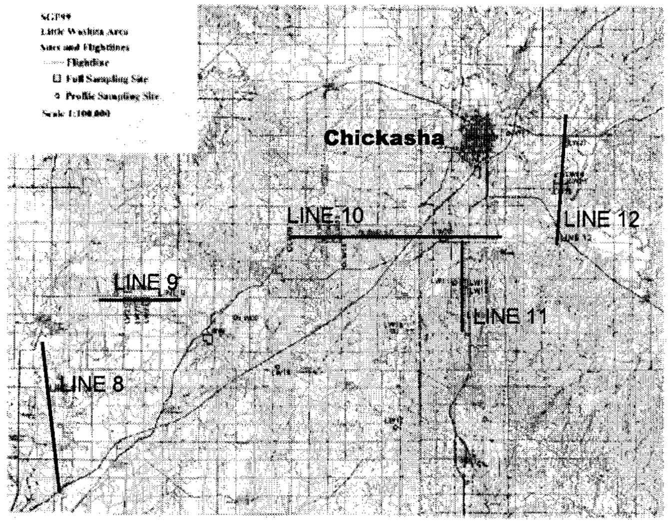

Fig. 1: SGP99 flight lines in the Little Washita area.

SITE DESCRIPTION AND FLIGHT LINES

A description of the SGP99 experiment is available at the SGP99 web site http://hydrolab.arsusda.gov/sgp99. Additional information is provided in [10]. The experiment included flights of five airborne microwave sensors: PSR-C, ESTAR, and ACMR on the NASA P-3 aircraft, and PALS and STEP-C on the NCAR C-130 aircraft. The C-130 flew at a nominal altitude of 3,000 feet over the SGP99 flight lines 8, 9, 10, 11, and 12 in the Little Washita area near Chickasha, OK, and line 13 further north near El Reno, OK. The Little Washita flight lines are shown in Fig. 1. Additional flight lines (9a through 9h) were included between lines 9 and 10 to provide contiguous mapping coverage of the Little Washita area. Line 8 over Lake Ellsworth was flown at the beginning of each day to obtain calibration data over a large water body of well-known emissivity characteristics. The data from line 8 were used to calibrate the radiometer data over all flight lines. The vegetation cover was fairly heterogeneous and included bare fields, crops, pasture (grassland), and wooded sites.

The P-3 aircraft flew predominantly north-south flight lines at high altitude, with the primary objective of wide-area mapping. The lines extended from the Little Washita area in the south to the ARM-CART Central Facility in the north near the Oklahoma state boundary. Two east-west lines were flown near El Reno, one of which duplicated, at higher altitude, line 13 flown by the C-130, so that a direct comparison could be made (although at different spatial resolution) of data from the microwave sensors on each aircraft. The C-130 flights were made generally between the hours of 8:30 am and 1:00 pm on six days: July 8, 9, 11, 12, 13, 14. On July 10 a rainstorm moved through the area, providing an excellent opportunity to observe drying conditions during July 11–14.

RESULTS

Fig. 2 shows PALS T_B data for flight line 9a (West-to-East) on the days immediately before and after the rain event. The increased soil moisture due to precipitation is seen as a decrease in T_B of up to 40 to 60 K at L-band. The East end of the flight line is more wooded and the effect of soil moisture change is less pronounced there. The greater attenuation at S-band than L-band due to vegetation is seen in the reduced polarization difference and sensitivity to moisture at S-band (although this is also contributed to by surface roughness and smaller soil penetration depth). Fig. 3 shows PALS radar backscatter (σ_o) data at L band, HH polarization, before and after the rain event. The radar data show the effect of soil moisture change as an increase in σ_o, but are more sensitive to the surface heterogeneity than the radiometer data. The radiometer and radar have been smoothed with an 8-second running average. In subsequent processing the radiometer and radar footprints will be carefully matched in location and spatial resolution to permit joint analysis of the two data sets.

SUMMARY

The PALS instrument acquired a new and substantial dataset during SGP99 with which studies of multichannel soil moisture and vegetation sensing can be pursued. In-situ data on soil and vegetation characteristics collected during the experiment will support these studies. Landsat TM imagery, and video data acquired simultaneously with the microwave data, will aid in identifying landcover features and their interpretation in the PALS data. Future experiments using PALS will seek to expand the database to surfaces with higher biomass and more varied topography.

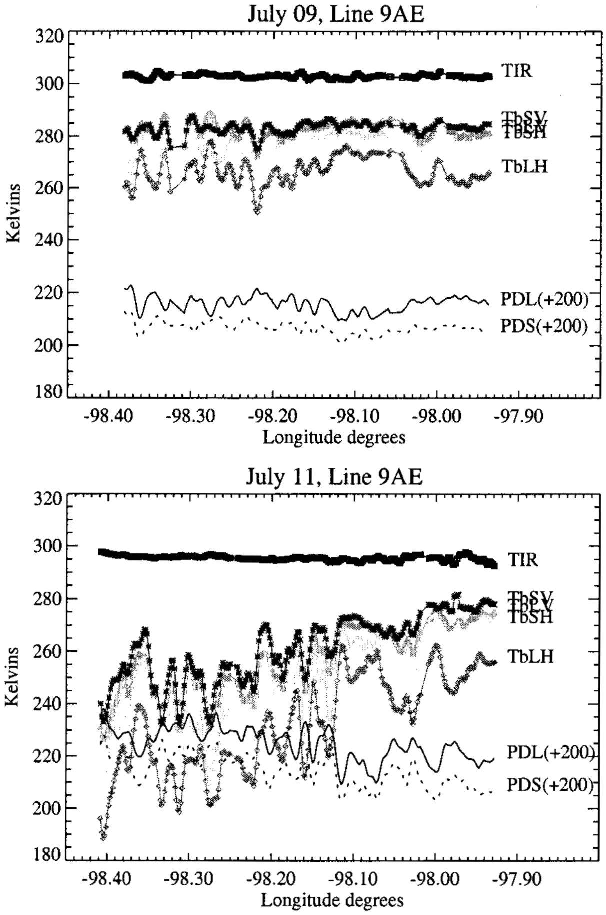

Fig. 2: PALS brightness temperatures at L and S bands, V and H polarization; polarization differences (PD) at L and S bands; and thermal IR surface temperatures (TIR). (Line 9AE refers to a West-to East flight over Line 9a.)

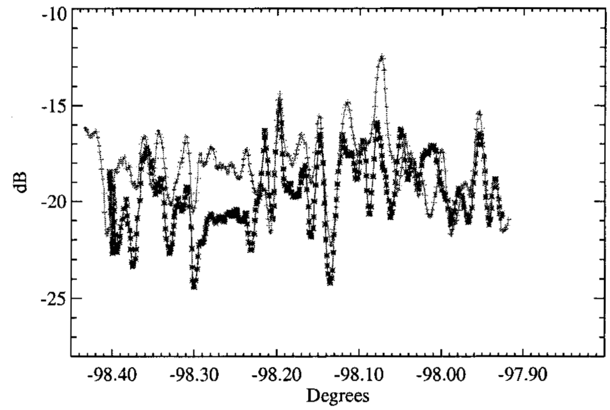

Fig. 3: PALS L band HH radar backscatter coefficient (σ_o), Line 9AE on July 9 (*—*) and July 11 (+—+). (See caption for Fig.2.)

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